Vienna,

$29^{\text{th}}$ August 2023

# Investigating the gamma-ray burst from decaying MeV-scale axion-like particles produced in supernova explosions

based on: JCAP **07** (2023), 056 & 2306.16397
in collaboration with: F. Calore, C. Eckner, A. Goobar, M. C. D. Marsh and E. Müller

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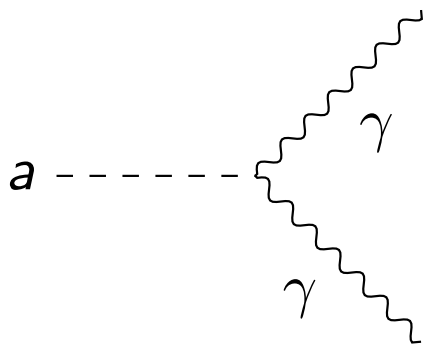
# Pragmatic introduction to ALPs

ALPs are pseudoscalars predicted by GUTs and String Theory

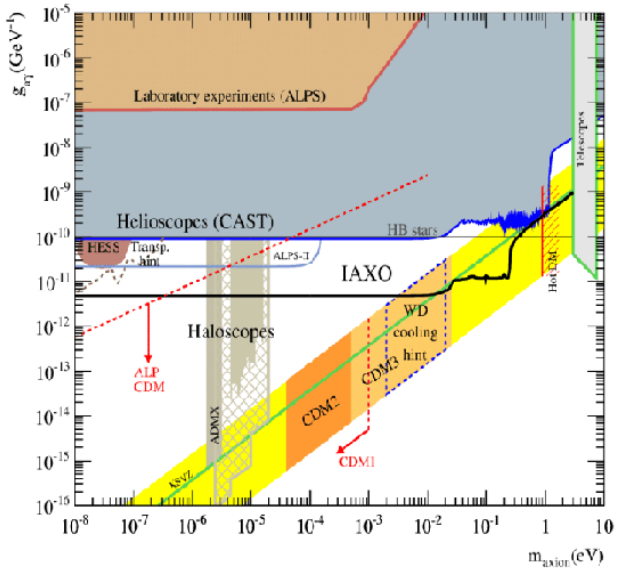
**ALP-photon vertex**

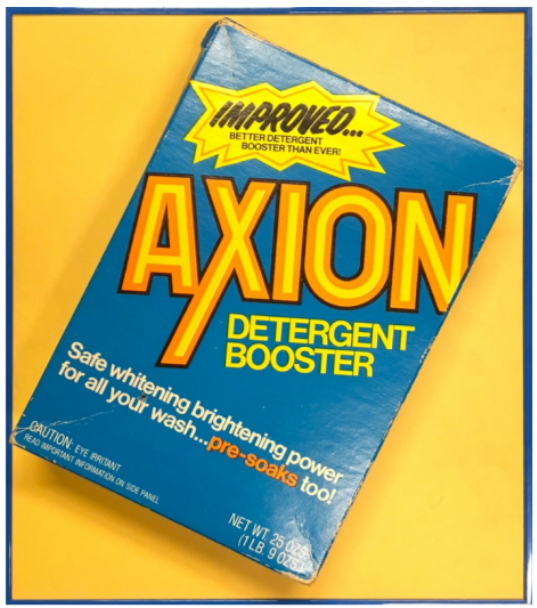
$$\mathcal{L}_{a\gamma} = -\frac{g_{a\gamma}}{4} a\, F_{\mu\nu}\tilde{F}^{\mu\nu} = g_{a\gamma}\, a\, \mathrm{E}\cdot\mathrm{B} \qquad g_{a\gamma} = C_\gamma \frac{\alpha}{2\pi f_a}$$

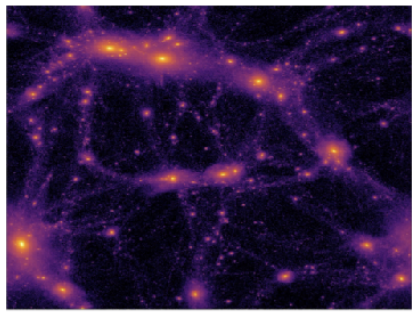


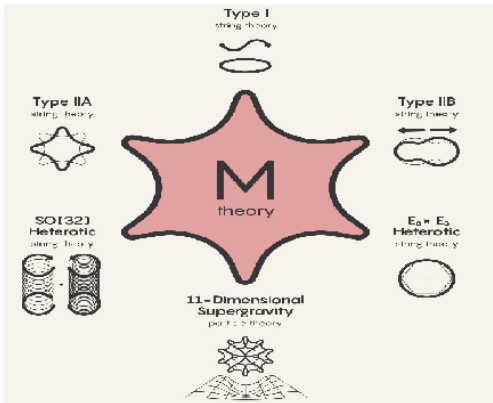
# Motivations to study ALPs

ALPs are a window on high-energy physics



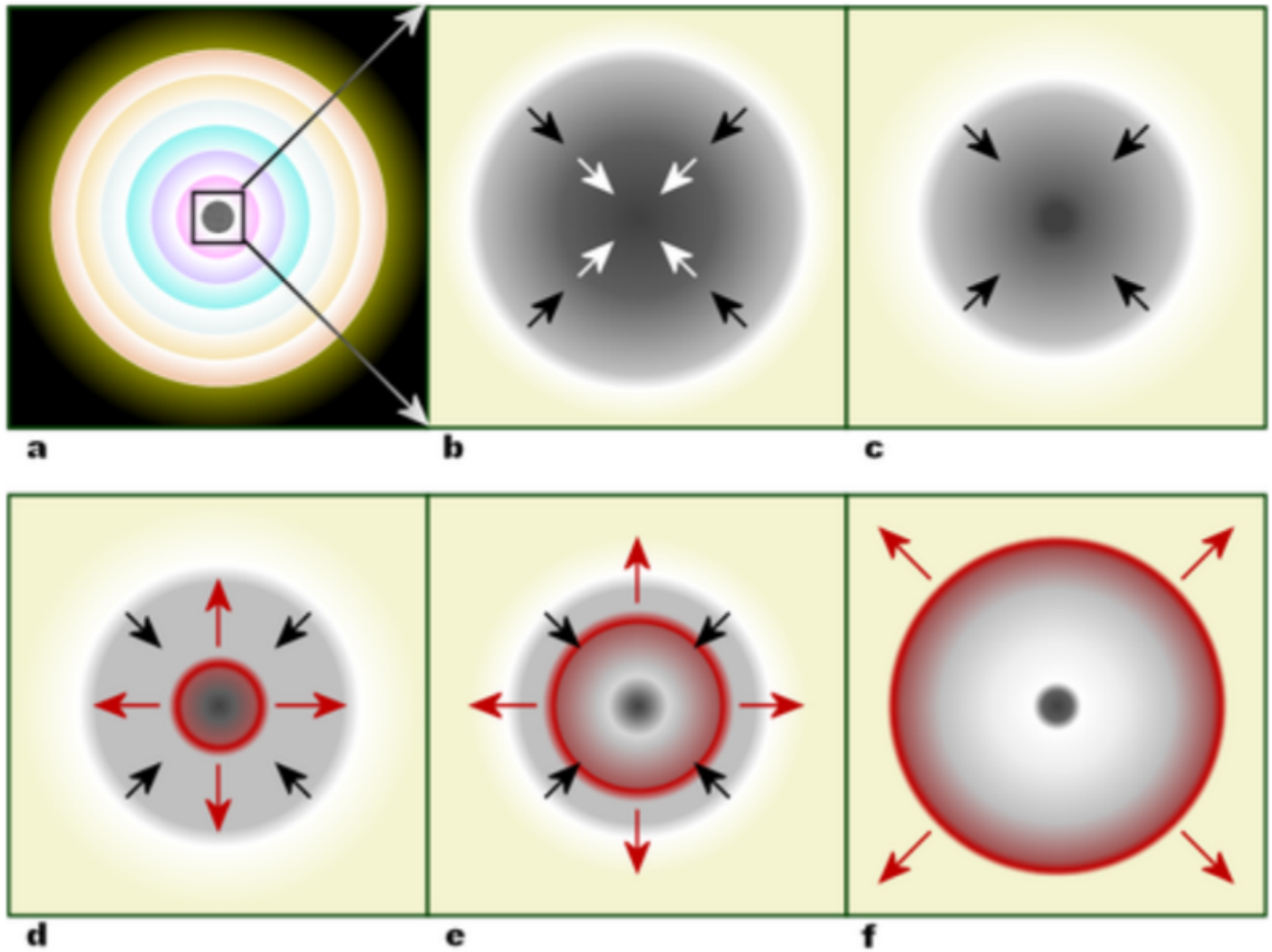






This hot topic is a motivation for interdisciplinary searches

# Core-Collapse Supernovae

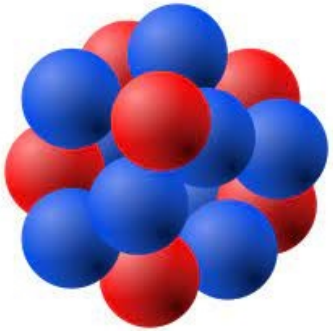
For massive stars ($M > 8M_{\odot}$) the nuclear fusion produces heavy elements in an onion structure and a degenerate iron core



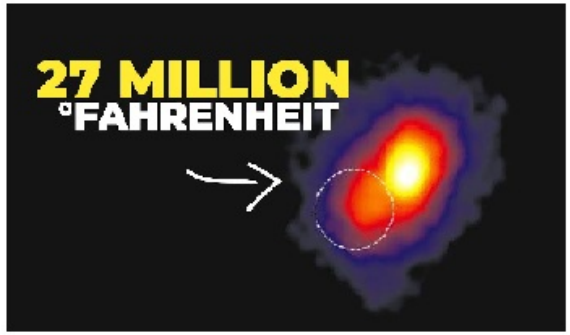

Iron in the core cannot be burnt and the star starts to collapse

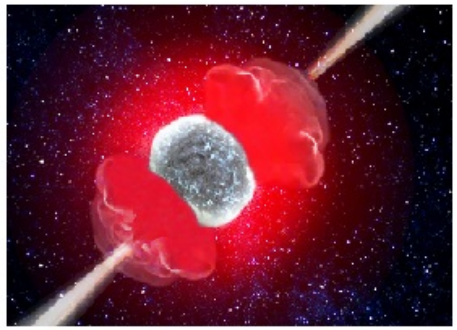
# Orders of magnitude for SNe

The SN core is an extreme environment



***1000x***



***density***

$10^{14}\mathrm{g\ cm^{-3}}$

***temperature***

$30\ \mathrm{MeV}$

***magnetic field***

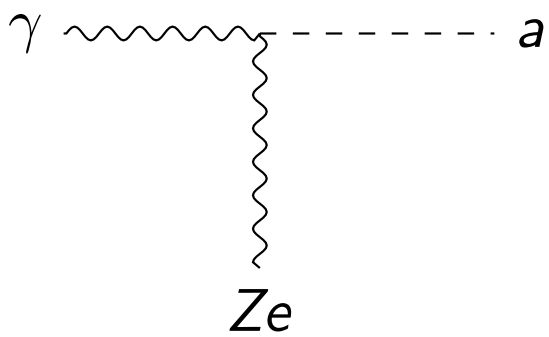
$10^{15}\,\mathrm{G}$

# ALP production channels

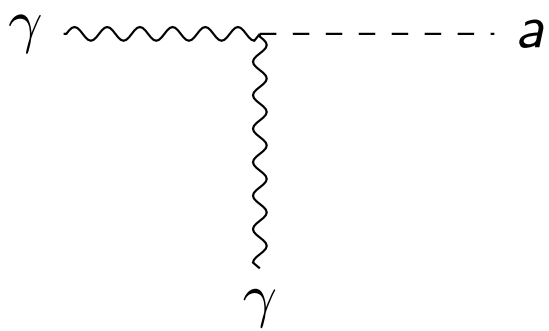
G. Lucente, PC *et al.*, JCAP **12** (2020), 008

ALPs are coupled with photons and are produced by:

Primakoff conversion



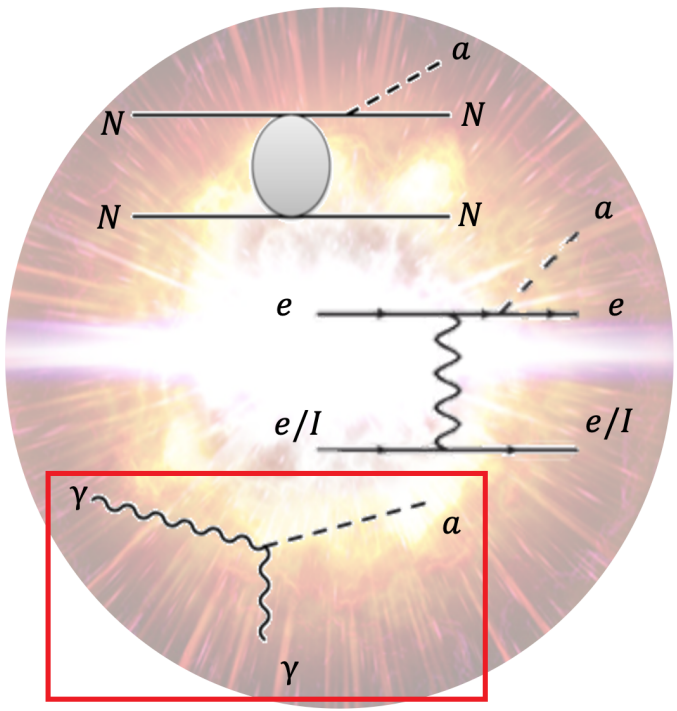

Inverse Decay



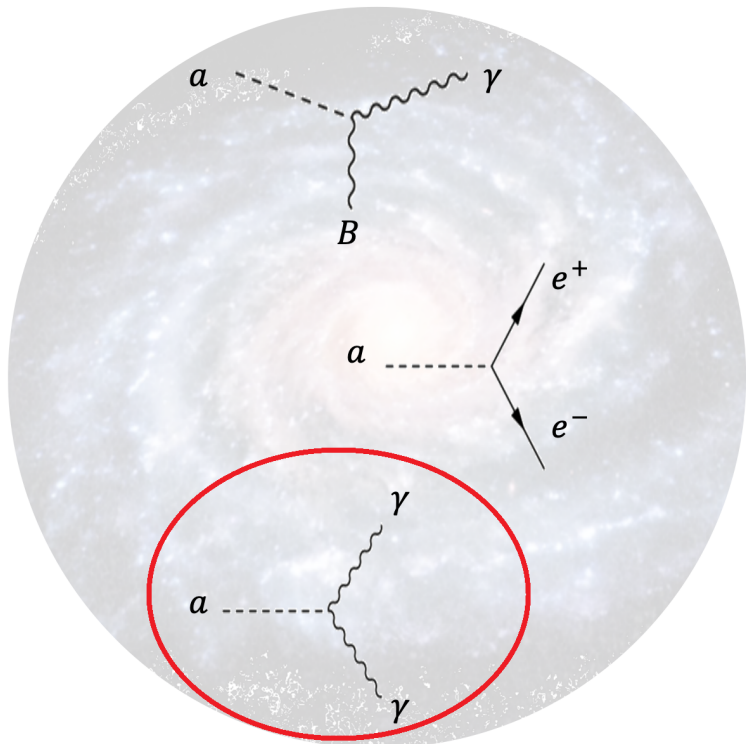
# SN ALP phenomenology: decay of heavy ALPs

JCAP **01** (2011), 015 , Phys. Rev. D **98** (2018) no.5, 055032 , JCAP **03** (2023), 054

**Production**




**Signature**



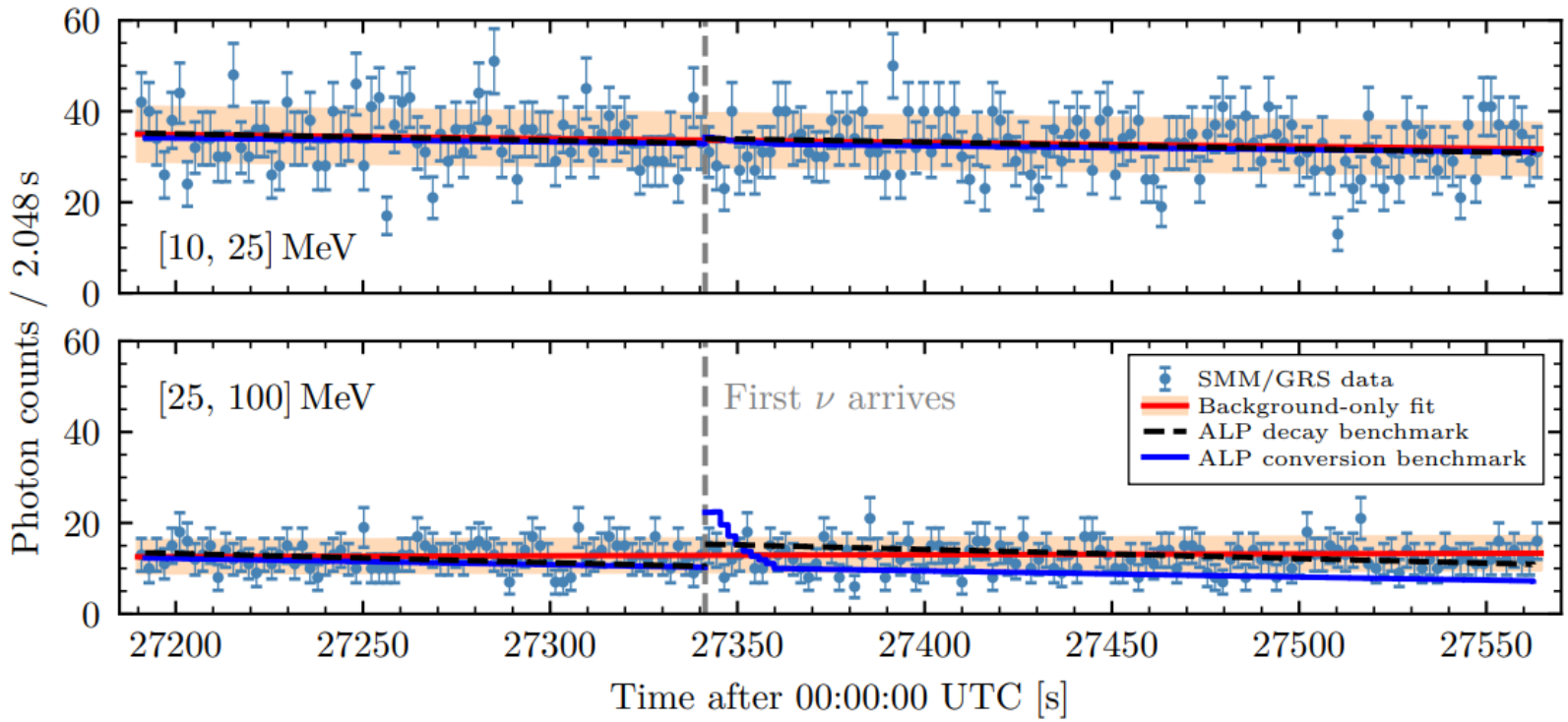
# The case of SN 1987A

An 18 $M_\odot$ type II SN in the Large Magellanic Cloud (51.4 kpc) on February 23, 1987

# No $\gamma$-ray excess from SN 1987A

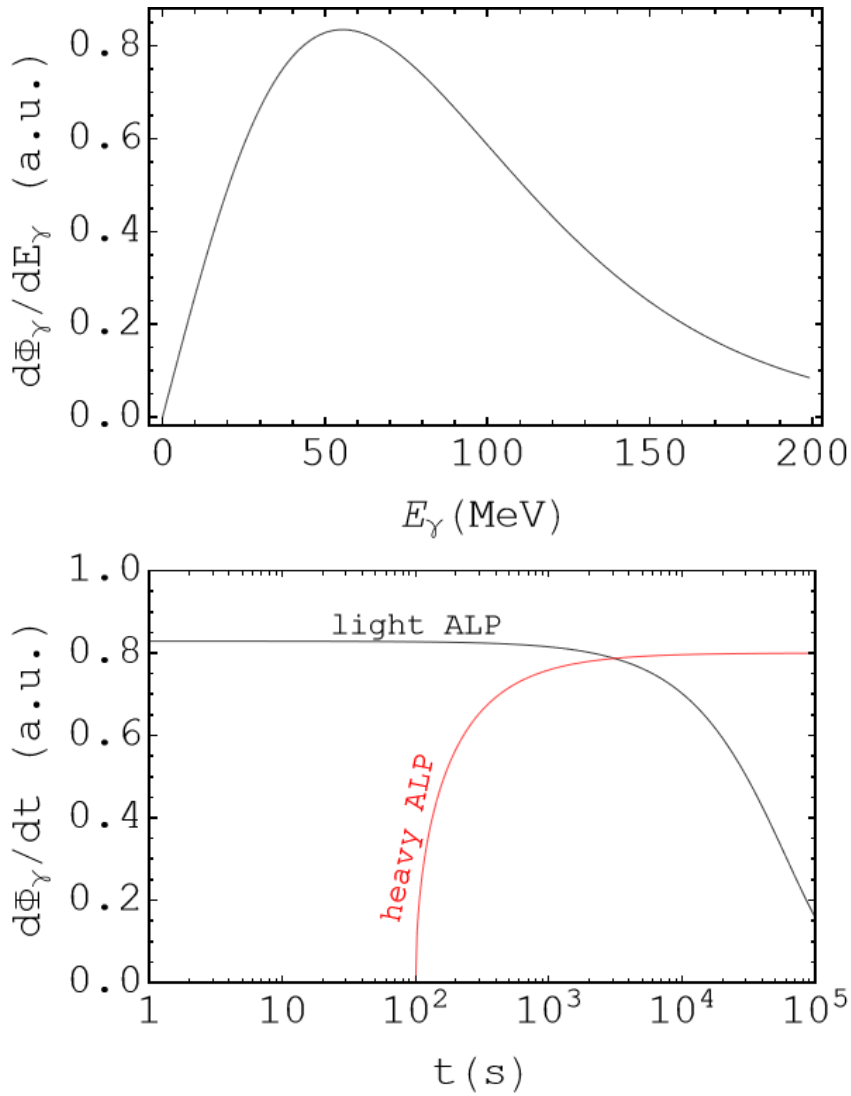
S. Hoof and L. Schulz, JCAP **03** (2023), 054

The GRS instrument found no $\gamma$-ray excess in coincidence with SN 1987A



# Expected ALP-induced $\gamma$-ray signal

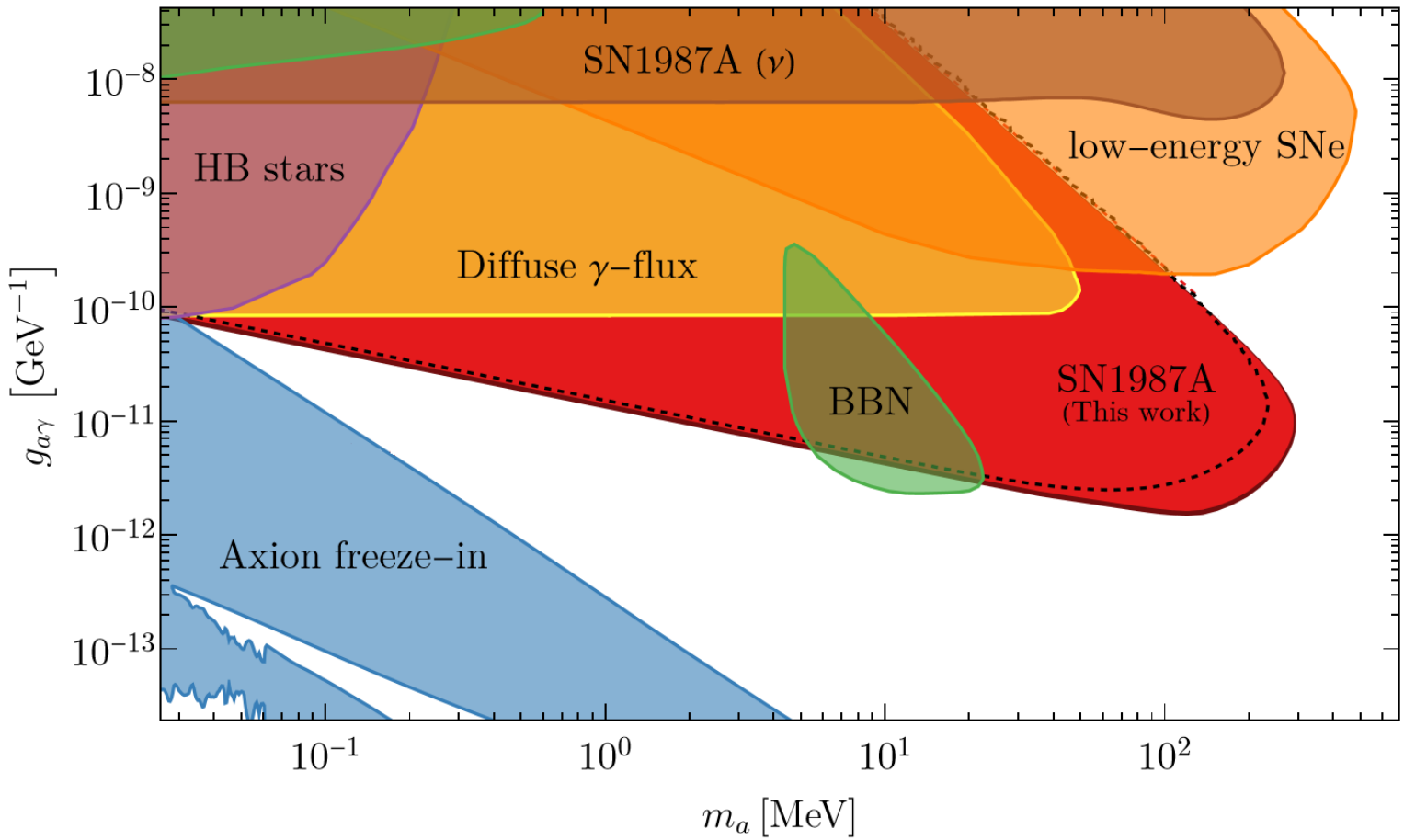
Energy and time-dependence of simulated spectra



# Revisiting the SN decay bound

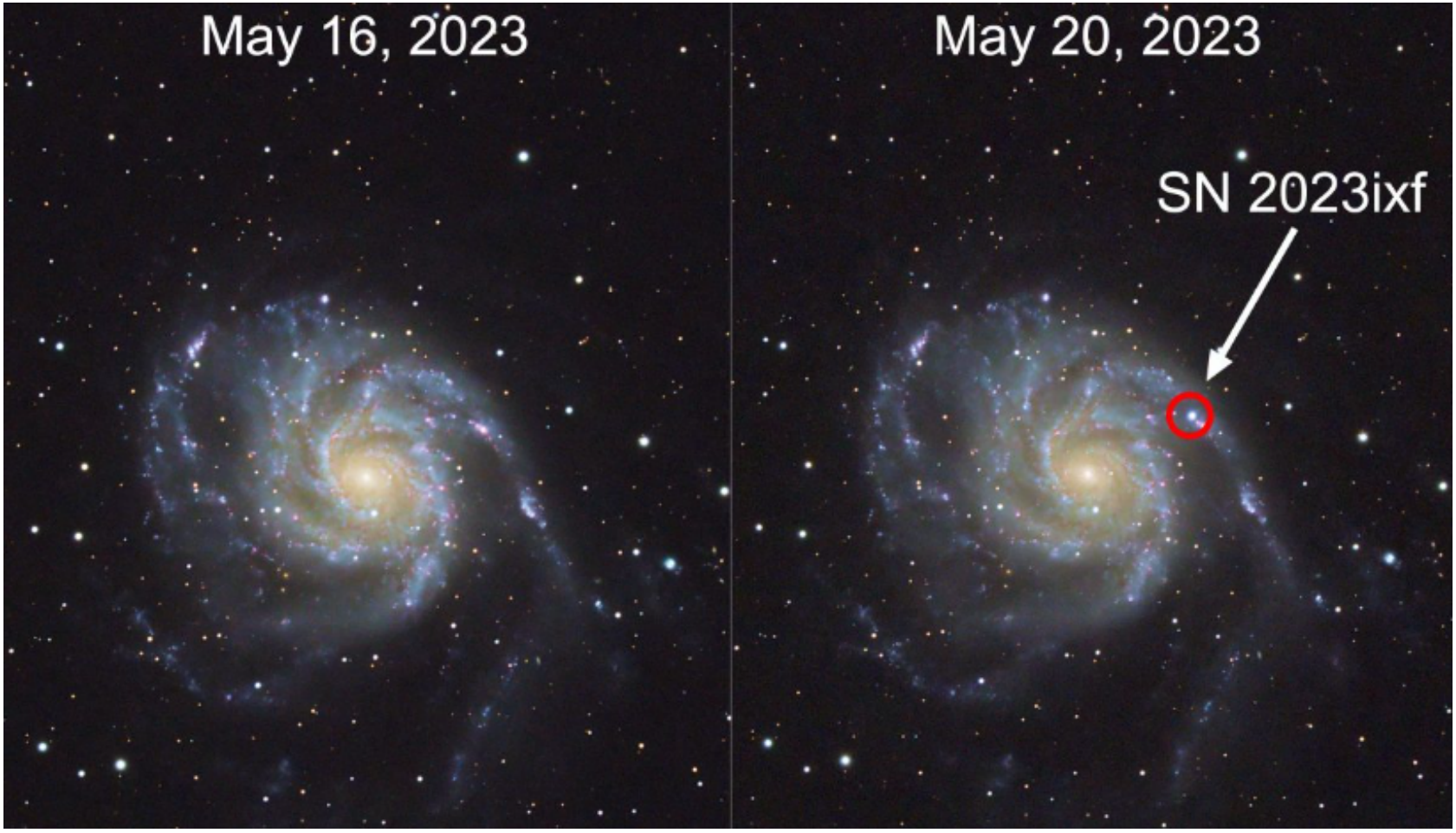
E. Müller, PC *et al.* JCAP **07** (2023), 056

The latest SN 1987A bound on decaying ALPs



# Application to SN 2023ixf

An $\sim 11\ M_\odot$ type II SN in M101 (6.85 Mpc) on May 18, 2023



# A lot of interest in SN 2023ixf

The bright supernova SN 2023ixf in Messier 101: online observation – 26 May 2023.

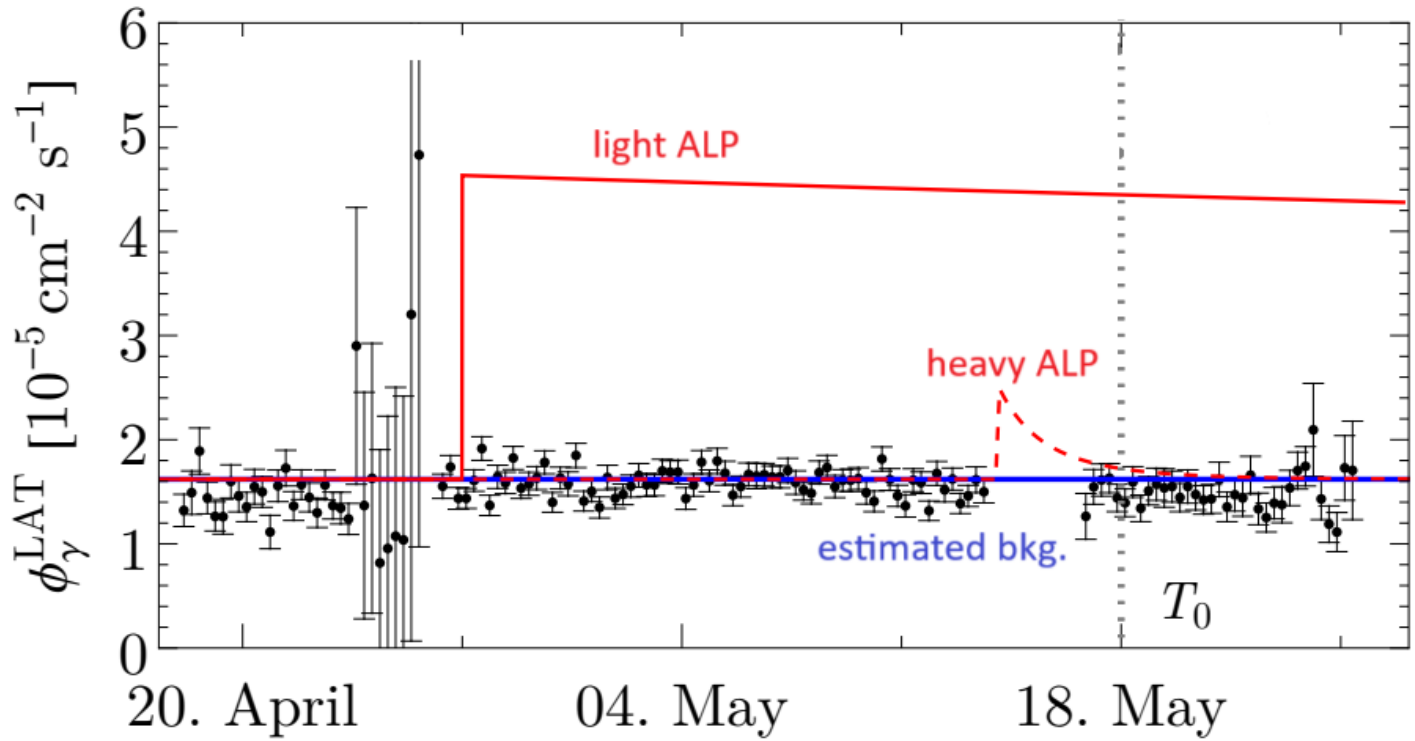
BY GIANLUCA MASI · 05/22/2023

Supernova **SN 2023ixf** is one of the brightest and closest ones seen in the last decade. Join our live feed to see this cosmic firework and its stunning host galaxy **Messier 101** in real-time.

- C. D. Kilpatrick *et al.* "SN 2023ixf in Messier 101: A Variable Red Supergiant as the Progenitor Candidate to a Type II Supernova," Astrophys. J. Lett. **952** (2023) no.1, L23
- L. A. Sgro *et al.* "Photometry of Type II Supernova SN 2023ixf with a Worldwide Citizen Science Network," Res. Notes AAS **7** (2023), 141

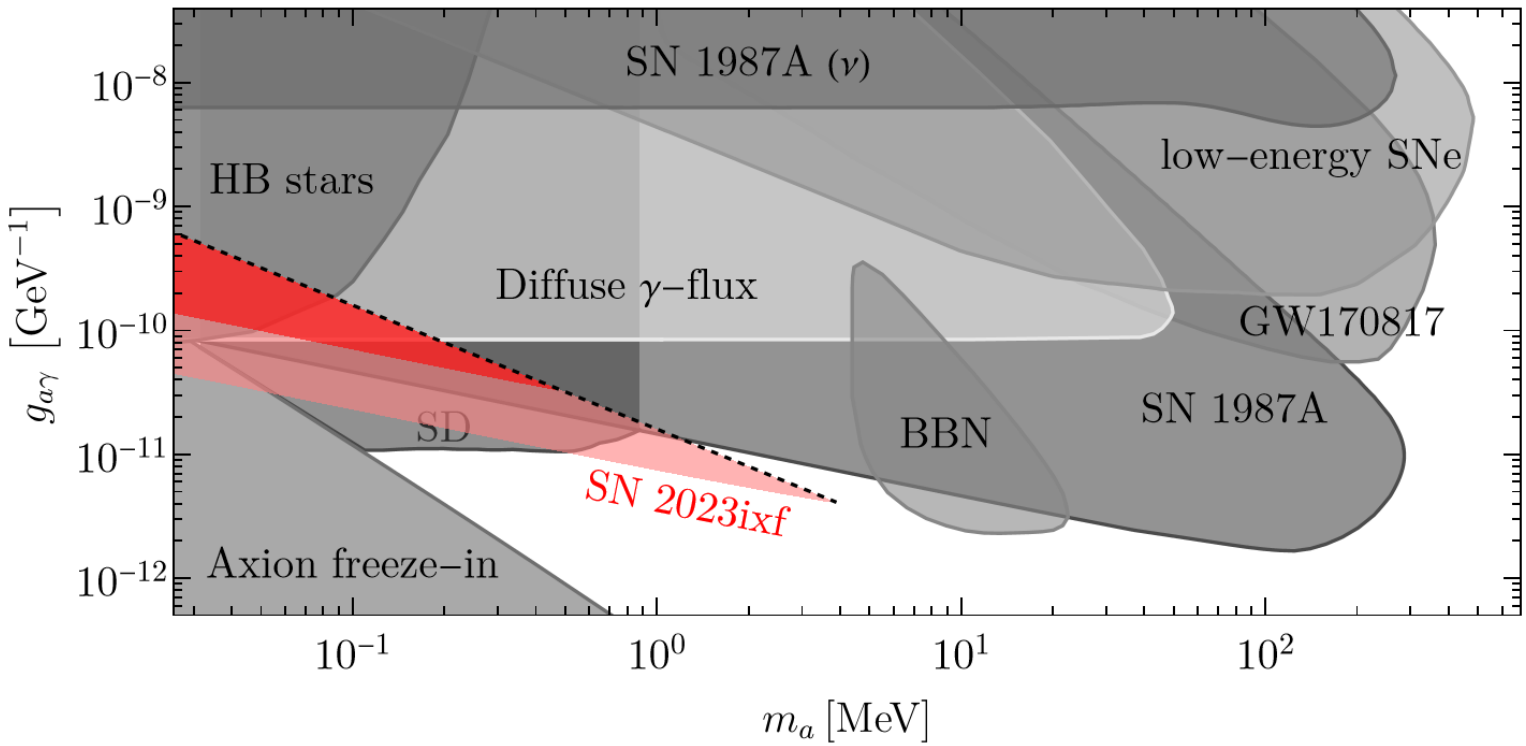
# What if ALPs from SN 2023ixf give rise to a $\gamma$-ray signal?

*Fermi*-LAT observation in direction of SN 2023ixf in the range $[30\ \mathrm{MeV}, 300\ \mathrm{GeV}]$

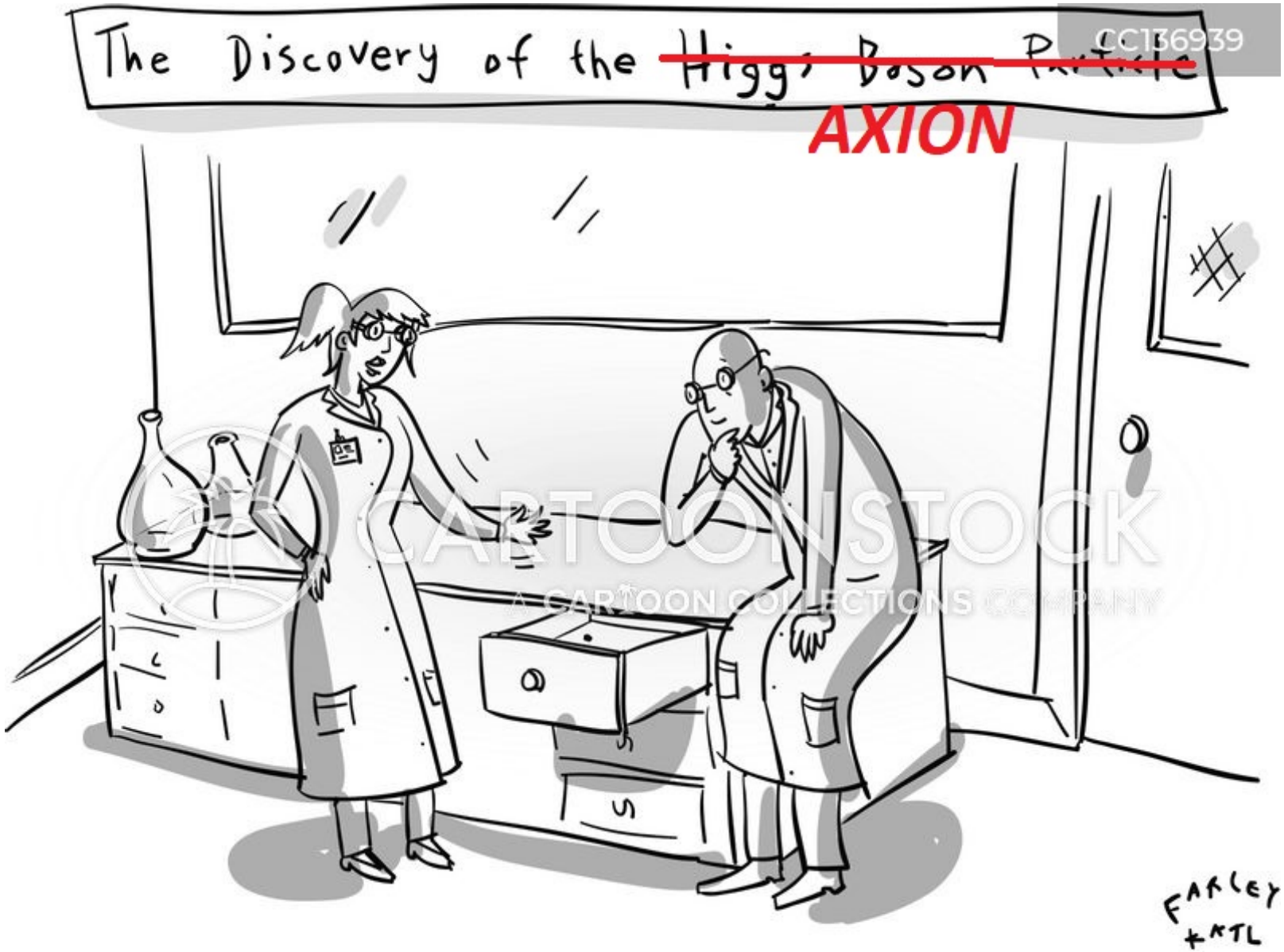


# ... it doesn't look to be the case :(

*Fermi*-LAT bound on heavy ALPs from SN 2023ixf



# Conclusions




*"Always the last place you look!"*